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AUTHOR Cochran, Kathryn F.; And Others
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ABSTRACT

The purpose of this paper is to present a brief overview of the nature of pedagogical content knowledge and to offer a list of working hypotheses concerning it for incorporation into teacher education programs. What teachers know about teaching, such as preinstructional strategies, the use of concrete examples and manipulatives, formative testing, use of questions, design of curriculum and assignments, and assessment of student performance, comprises pedagogical knowledge. Pedagogical content knowledge is a type of knowledge unique to teachers; it concerns the manner in which teachers relate their pedagogical knowledge to their subject matter knowledge in the school context, for the teaching of specific students. The integration of teachers' pedagogical knowledge and their subject matter knowledge comprises pedagogical content knowledge. This paper summarizes the state of current research and describes a tentative model for use in teacher preparation programs. A list of working hypotheses based on current knowledge is presented to serve as a basis for future theoretical and applied research. (LL)

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Pedagogical content knowledge:

A Tentative Model for Teacher Preparation

Kathryn F. Cochran
Richard A. King
James A. DeRuiter
University of Northern Colorado

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Abstract

This paper presents a brief overview of the nature of pedagogical content knowledge, that knowledge about teaching specific subject matter concepts to specific students that is unique to teachers. The state of current research is summarized, and a tentative model for use in teacher preparation programs is described. A list of working hypotheses based on current knowledge is presented to serve as a basis for future theoretical and applied research.

Pedagogical content knowledge: A Tentative Model for Teacher Preparation

"Those who can, do. Those who understand, teach."
(Shulman, 1986, p. 14)

The early history of teacher education was primarily focused on a teacher's knowledge of subject matter content (Shulman, 1986). However, for the past few decades, teacher education research has been mainly focused on the effectiveness of general pedagogical methods independent of subject matter content (Ball & McDiarmid, 1990) such as the teacher's use of questions, the design of assignments and curriculum, and the assessment of student performance. This work has revealed that a significant number of instructional strategies improve student achievement, such as wait time, preinstructional strategies, the use of concrete examples and manipulatives, and formative testing (see, e.g., Hofwolt, no date, for a review). For the most part, these issues have been researched in the general classroom context, isolated from specific content material. Where content has been included, it has served primarily as a control variable rather than a topic of specific interest.

Recently, there has been a renewed recognition of the importance of teachers' subject matter knowledge, both as a function of research evidence (e.g., Ball & McDiarmid, 1990; Carlsen, 1987; Hashweh, 1987), and as a function of recent literature from reform initiatives such as the Holmes Group (1986) and the Renaissance Group (1989). Not surprisingly, it has become clear that <u>both</u> teachers' pedagogical

knowledge and teachers' subject matter knowledge are crucial to good teaching and student understanding (Buchmann, 1982, 1983; Doyle, 1986; Feiman-Nemser & Buchmann, 1987; Tobin & Garnett, 1988).

The Nature of Pedagogical Content Knowledge

In addition to teachers' subject matter (content) knowledge and their knowledge of general instructional methods (pedagogical knowledge), Shulman (1986, 1987) has suggested that teaching expertise should be described and evaluated (Shulman, 1988) in terms of pedagogical content knowledge. This notion has been a major outcome of the Stanford Knowledge Growth in Teaching Project conducted by Shulman and his colleagues and students (e.g. Carlsen, 1987; Grossman, Wilson, & Shulman, 1989; Gudmundsdottir, 1987a, 1987b; Gudmundsdottir & Shulman, 1987; Marks, 1990), and represents a new, broader perspective in our understanding of teaching and learning. A recent special issue of the Journal of Teacher Education (Ashton, 1990) has been devoted to this topic.

Pedagogical content knowledge is a type of knowledge that is unique to teachers, and in fact is what teaching is about. It concerns the manner in which teachers relate their pedagogical knowledge (what they know about teaching) to their subject matter knowledge (what they know about what they teach), in the school context, for the teaching of specific students. It is the integration or the synthesis of teachers' pedagogical knowledge and their subject matter knowledge that comprises pedagogical content knowledge. According to Shulman (1986), pedagogical content knowledge

> . . ."embodies the aspects of content most germane to its teachability. Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations - in a word, the ways of representing and formulating the subject that make it comprehensible to others . . . [It] also includes an understanding of what makes the learning of specific concepts easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning. (p. 9)

Pedagogical content knowledge is that form of knowledge that makes teachers <u>teachers</u> rather than subject area experts (Gudmundsdottir, 1987a, b). Teachers differ from biologists, historians, writers, or educational researchers, not necessarily in the quality or quantity of their subject matter knowledge, but in how that knowledge is organized and used. For example, an experienced science teacher's knowledge of science is structured from a <u>teaching</u> perspective and is used as a basis for helping students to understand specific concepts. A scientist's knowledge, on the other hand, is structured from a <u>research</u> perspective and is used as a basis for the construction of new knowledge in the field.

What is unique about the teaching process is that it requires teachers to "transform" their subject matter knowledge for the purpose of teaching (Shulman, 1986). This transformation occurs as the teacher *critically reflects* on and *interprets* the subject matter; finds multiple ways to *represent* the information as analogies, metaphors, examples, problems, demonstrations, and classroom activities; *adapts* the material to students' abilities, gender, prior knowledge, and misconceptions; and finally *tailors* the material to

those specific students to whom the information will be taught. Gudmundsdottir (1987a, b) describes this transformation process as a continual restructuring of subject matter knowledge for the purpose of teaching; and Buchmann (1984) discusses the notion that good teachers must maintain a fluid control or "flexible understanding" (p. 21) of their subject knowledge, i.e. be able to see a specific set of concepts from a variety of viewpoints and at a variety of levels, depending on the needs and abilities of the students.

It is important to note that a teacher's transformation of subject matter knowledge occurs in the context of two other important components of teacher knowledge which differentiate teachers from subject matter experts. One is a teacher's knowledge of students, including their abilities and learning strategies, ages and developmental levels, attitudes, motivations, and their prior knowledge of the concepts to be taught. The influence of students' prior knowledge on learning has become especially clear in the last decade due to literally hundreds of studies on student misconceptions, particularly in science and mathematics. The other component of teacher knowledge that contributes to pedagogical content knowledge is teachers' understanding of the social, political, cultural and physical environments in which students are asked to learn.

Research Evidence: Some Examples

Current research, much of it conducted as part of the Stanford project, has shown that inexperienced teachers have incomplete and superficial levels of pedagogical content knowledge (Carpenter, Fennema, Petersen, & Carey, 1988; Feiman-Nemser & Parker, 1990;

Gudmundsdottir & Shulman, 1987; Shulman, 1987). A novice teacher tends to rely on unmodified subject matter knowledge (most often directly extracted from the text or curriculum materials) and may not have a coherent framework or perspective from which to present the information. The novice also tends to make broad pedagogical decisions (such as whether or not to use cooperative learning) without assessing students' prior knowledge, ability levels, or learning strategies (Carpenter, et al., 1988). In addition, low levels of PCK have been found to be related to frequent use of factual and simple recall questions (Carlsen, 1987), which are easy for a novice teacher to quickly evaluate and require less "on the spot" analysis of the learning setting.

Studies also indicate that novice teachers have major concerns about pedagogical content knowledge, and they struggle with how to transform and represent the concepts and ideas in ways that make sense to the specific students they are teaching (Feiman-Nemser & Parker, 1990; Wilson, Shulman & Richert, 1987). A study by Grossman (1989) shows that this concern is present even in new teachers who possess the substantial subject matter knowledge gained through a master's degree in a specific subject matter area, in this case, in English. Grossman's work focused on six teachers in their first year of teaching English, three of them having substantial subject matter background but no formal teacher training. The other three had completed a teacher education program with a strong subject matter component. In Grossman's study, the teachers without formal teacher education planned and taught English as a formal discipline, and two of

the three in particular focused on the literary analysis aspects of the texts to be read. The teachers with professional teacher education, however, were more focused on the need to relate the readings to the students' experiences, and to use the texts as a basis for learning skills of communication and self-expression. These differences in the two groups of teachers were also evident in their choices of readings, the professionally prepared teachers choosing texts more relevant to students' interests, and organized their courses around writing instead of literature.

The two groups of teachers also differed in their expectations and knowledge of students, with the professionally prepared teachers being much less suprised by students' misconceptions and lack of understanding. The teachers with only subject matter preparation did realize that they needed to take student prior knowledge into account. However, they had difficulty making decisions about the best instructional steps to take, and in some cases, inappropriately concluded that the problem was really the students' levels of motivation or ability. The professionally prepared teachers had a framework for dealing with student needs constructed during their professional program and adjusted more effectively to the diverse needs of the students in their classrooms.

In another example, Hashweh (1985, 1987) conducted an extensive study of three physics teachers' and three biology teachers' knowledge of science and the impact of that knowledge on their teaching. All six teachers were asked about their subject matter knowledge in both biology and physics, and they were asked to evaluate

a textbook chapter and to plan an instructional unit on the basis of that material. Given a concept like photosynthesis for example, the biology teachers knew those specific misconceptions that students were likely to bring to the classroom (such as the idea that plants get their food from the soil) or which chemistry concepts the students would need to review before learning photosynthesis. The biology teachers also understood which ideas were likely to be rather difficult (e.g. the dark phase of photosynthesis) and how best to deal with those difficult concepts using a variety of analogies, examples, demonstrations and models. The biology teachers could describe multiple instructional "tools" for these situations; but although they were experienced teachers, they had only very general ideas about how to teach difficult physics concepts. The physics teachers, on the other hand, could list many methods and ideas for teaching difficult physics concepts, but had few specific ideas for teaching difficult biology concepts.

Predictably, when the teachers in Hashweh's study were asked about their subject matter knowledge outside their fields, they showed more misconceptions and a less organized understanding of the information which directly carried over into their plans for teaching the content. Within their own fields, the teachers were more sensitive to subtle themes presented in textbooks, and could and did modify the text material based on their teaching experiences. Moreover, they were more likely to discover and instructionally deal with student misconceptions. The teachers in both fields used about the same number of examples and analogies when planning instruction, but those

analogies and examples were more accurate and more relevant in the teachers' field of expertise.

Although the case study approaches used in many of these studies do not necessarily allow broad generalizations about teacher knowledge, the combination of these results and others show that pedagogical content knowledge is highly specific to the concepts being taught, is much more than just subject matter knowledge alone, and develops over time as a result of experience in many classroom settings with many students.

The Application of PCK to Teacher Preparation

Last year at the University of Northern Colorado, we began a theoretical and philosophical analysis of teacher preparation funded by the Carnegie Foundation's Project 30 initiative. We created seven teams composed of faculty and adminstrators from the colleges of Arts and Sciences, Education, and Health and Human Services, and we held a one-week retreat to focus on the process of rethinking and redesigning teacher education. One of those teams concentrated on PCK and how it might be applied to the education of teachers and was composed of the three authors of this paper and faculty members from Biological Sciences, Mathematics, and Physical Education, and the Dean of the College of Education.

Based on our reading of the current literature, we defined pedagogical content knowledge from a constructivist perspective (e.g., von Glasersfeld, 1984; Newman, Griffin & Cole, 1989) as follows:

> Pedagogical content knowledge is an integrated understanding that is synthesized from teacher knowledge of pedagogy, subject matter content, student characteristics, and the environmental context of

> learning. In other words, PCK is using the understandings of subject matter concepts, learning processes, and strategies for teaching the specific content of a discipline in a way that enables students to construct their own knowledge effectively in an given context.

Figures 1 and 2 show a two-stage model of PCK elaborated from the one we developed in our PCK faculty analysis team for possible use as a guideline for teacher preparation programs. There are four areas of knowledge, the amalgam of which comprises PCK. They are content (subject area) knowledge, pedagogical knowledge, knowledge of students (e.g., their prior subject area knowledge, motivation, and backgrounds), and knowledge of the environmental context (e.g., knowledge of the school climate, parental concerns, legal issues, and the social context of the community). Our definition is somewhat, although not radically different from Shulman's in that we have put relatively more emphasis on the environmental context of learning and the teacher's knowledge of students. Shulman (1987) has also discussed several other types of knowledge, including knowledge of curriculum, knowledge of educational goals and purposes, and knowledge of other content. We have elected to subsume the first two of these types of knowledge under general pedagogical knowledge, although as research in these areas proceeds, the segregation of these other knowledge types might be useful. The final type of knowledge, knowledge of other content, refers to a teacher's "non-target" content knowledge which is not directly related to the subject being taught (the "target" content). Since Hashweh (1987) has shown that this knowledge also impacts teaching, and is a source of misconceptions directly communicated to students, we assume it to be included under subject mattter knowledge.

Insert Figures 1 & 2 about here

The four components of PCK in our model are represented as circles expanding with experience because a preservice teacher's knowledge in each of these four areas can be thought of as beginning with a relatively limited focus and becoming elaborated with experience and reflective activities (Schon, 1987; Shulman, 1987) during a teacher preparation program and beyond. The growth of pedagogical content knowledge is indicated by the dark arrows and the expanding core of the model from novice to experienced teacher. The four separate knowledges are transformed and synthesized as PCK evolves, and theoretically, the four components become so integrated and so interrelated that they no longer can be considered separate knowledges. These integration processes should result in conceptual change and conceptual integration to the point that the resulting PCK knowledge, the expertise of teaching, is distinctively different from types of knowledge from which it was constructed.

Since we have described PCK as an integrated or synthesized knowledge, the development of the knowledges that form the basis for the integration must therefore coincide. We do not mean to suggest that the four knowledge types should be acquired "first" and then be somehow "put together". To use an analogy, we would describe the development of PCK, not as a salad where the ingredients are merely added together and still retain their individual identities (requiring dressing to blend them together), but rather more similar to chocolate

mousse, where the merging of ordinary ingredients results in an entirely new and extraordinary outcome.

The circles surrounding the PCK core are not concentric or symmetrical in the models because the pattern of PCK development is likely to vary somewhat from one time to another. Depending on the nature and the order of the experiences in the program, the four types of knowledges may be unevenly developed and integrated as a preservice teacher negotiates the preparation process. For example, the initial hours that preservice teachers spend observing in classrooms are likely to foster development of knowledge of the school context more so than content knowledge per se, but the novices' first attempts at teaching difficult subject matter concepts will contribute to the development of content knowledge and knowledge of students. To the extent that both of these activities occur in the same or similar settings, the preservice teachers' knowledge bases in these areas will become integrated to form the beginnings of PCK. In addition, the process is not likely to be a uniform one. It might very well be characterized by qualitative alterations in the shape and extent of PCK core knowledge.

Working Hypotheses

We would like to outline a series of working hypotheses which seem reasonable, given what we know so far about pedagogical content knowledge and how it might be applied to teacher education programs. Some of these ideas are new and some have been certainly been suggested before. We think it is important, however, to identify them and promote their discussion in the context of the development of

pedagogical content knowledge. Moreover, some of the ideas are speculative ones and represent admittedly substantial inferences beyond the actual data.

1. Providing preservice teachers with a solid foundation of PCK requires strong preparation in liberal arts, pedagogy, and specific subject matter content. This idea is partially based on Hashweh's (1987) work showing that subject matter knowledge outside a teacher's specific field can be a source of student misconceptions. This issue is becoming a particularly critical one with respect to subject matter knowledge and the preparation of elementary and middle school teachers, who need both a broad and a proficient subject matter background.
2. PCK development requires conceptually integrated instruction across liberal arts, pedagogy, and subject area courses in order for these types of knowledge to develop concurrently. As example of how this integration might be accomplished in the case of the latter two areas is now taking place at the University of Northern Colorado. The Pre-Service Elementary Mathematics/Science Project, an NSF funded project now in its fourth year, has allowed the development of an innovative preservice program. In an undergraduate Educational Psychology course, for example, theoretical ideas regarding learning and human development have been directly tied to subject area courses and methods courses in mathematics and science. We have asked students to look at a geoboard activity used in a previous methods course and to analyze it from the perspective of information processing theory. We have

required mathematics and science content in microteaching assignments, and used specific science topics (e.g. the solar system) to demonstrate the importance of providing students with concrete representations and examples of concepts. Another method for providing for this level of integration would be for methods courses to accompany or directly follow related content courses as suggested by Marks (1990).

3. Preservice program faculty development is necessary to assist instructors of subject matter content knowledge and pedagogical knowledge to be able to demonstrate and reflect upon uses of PCK in their own teaching. University faculty need to understand the nature of PCK in order to facilitate its development in teacher education students.
4. Cooperation between subject area faculty and pedagogy faculty, and substantial and innovative course development and revision, will be required.
5. Program faculty must model the awareness of PCK by sharing teaching decisions and strategies with students. We must practice what we teach.
6. Due to its integrated nature, PCK development cannot only occur in a separate course, such as a capstone seminar.
7. How we develop PCK in teacher preparation programs may depend on the grade level focus of those programs. Since our present knowledge of PCK is still superficial, we do not know how or whether teachers' PCK differs across grade levels. There may well be a very different set of experiences that will benefit elementary

and middle preservice teachers compared to secondary preservice teachers.

8. The construction of pedagogical content knowledge results from multiple opportunities to teach, and to observe and to reflect on one's own teaching and that of others in a content area. Tamir (1988) identifies microteaching activities as especially likely to be productive for the development of teacher pedagogical content knowledge; and Livingston and Borko (1989) and Wilson, et al. (1987) and others have identified multiple opportunities for teaching and reflection as important components of teacher preparation.
9. Development of PCK requires early, continued, and authentic field experiences with opportunities for "real teaching" and followup reflection and feedback. One way in which this might be accomplished is to enlist the involvement of experienced teachers in teacher preparation programs to a much greater extent than is currently occurring. Preservice teachers should be in direct professional contact with experienced teachers starting with the first year of their preservice programs. The NSF Preservice project at UNC has incorporated mentor teachers into all project courses, both pedagogy courses and subject area courses. Another NSF project, one focused on the incorporation of hypermedia technology at Vanderbilt (Goldman & Barron, 1990), has utilized the expertise of "consultant" teachers. In addition, Feiman-Nemser & Parker (1990) report a study of conversations between mentor

teachers and novice teachers and show that novices benefit with respect to many types of knowledge in such settings.

10. Peer coaching, cooperative classroom activities, analysis of case studies, and team teaching will facilitate PCK development.
11. PCK development continues beyond initial licensure (or certification) and should be an integral part of inservice professional development.

We would like the above list to be the focus of and an impetus for future research, both theoretical research conducted from the perspective of the construction of knowledge, and applied research conducted with preservice and experienced teachers. There are many things we do not yet know about PCK and its development, and the high level of specificity of PCK with respect to subject matter concepts makes it difficult to determine how best to prepare teachers with a solid basis of pedagogical content knowledge. When teacher preparation programs can be delivered by cooperatively combining the expertise of pedagogical experts, subject area specialists, and experienced teachers; and if we can accurately and appropriately evaluate the effectiveness of the methods and procedures we use in those programs, we might achieve such a goal.

References

Ashton, P. T. (Ed.). (1990). Theme: Pedagogical Content Knowledge [Special issue]. Journal of Teacher Education, 41(3).

Ball, D. L. & McDiarmid, G. W. (1990). The subject matter preparation of teachers. In W. R. Houston, M. Haberman, & J. Sikula (Eds.). Handbook of research on teacher education (pp. 437-449). New York: Macmillan.

Buchmann, M. (1982). The flight away from content in teacher education and teaching. Journal of Curriculum Studies, 14, 1.

Buchmann, M. (1984). The flight away from content in teacher education and teaching. In J. Raths & L. Katz (Eds.). Advances in teacher education (Vol.1, pp. 29-48). Norwood, NJ: Ablex.

Carlsen, Wm. S. (1987). Why do you ask? The effects of science teacher subject-matter knowledge on teacher questioning and classroom discourse. Paper presented at the Annual Meeting of the American Educational Research Association. (ERIC Document Reproduction Service NO. ED 293 181).

Carpenter, T. P., Fennema, E., Petersen, P. & Carey, D. (1988). Teachers' pedagogical content knowledge of students' problem solving in elementary arithmetic. Journal for Research in Mathematics Education, 19, 385-401.

Doyle, W. (1986). Content representations in teachers' definitions of academic work. Journal of Curriculum Studies, 18, 365-379.

Feiman-Nemser, S. & Buchmann, M. (1987). When is student teaching teacher education? Teaching and Teacher Education, 3, 255-273.

Feiman-Nemser, S. & Parker, M. B. (1990). Making subject matter part of the conversation in learning to teach. Journal of Teacher Education, 41(3), 32-43.

von Glasersfeld, E. (1984). An introduction to radical constructivism. In P. Watzlawick (Ed.). The Invented Reality. New York: Norton.

Goldman, E. & Barron, L. (1990). Using hypermedia to improve the preparation of elementary teachers. Journal of Teacher Education, 41(3), 21-31.

Grossman, P. L. (1989). A study in contrast: Sources of pedagogical content knowledge for secondary english. Journal of Teacher Education, 40(5), 24-31.

Grossman, P. L., Wilson, S. M., & Shulman, L. (1989). Teachers of substance: Subject matter knowledge for teaching. In M. C. Reynolds (Ed.). Knowledge base for the beginning teacher (pp. 23-36). Oxford: Pergamon Press.

Gudmundsdottir, S. (1987a). Learning to teach social studies: Case studies of Chris and Cathy. Paper presented at the Annual Meeting of the American Educational Research Association. Washington, D.C. (ERIC Document Reproduction Service NO. ED 290 700)

Gudmundsdottir, S. (1987b). Pedagogical content knowledge: Teachers' ways of knowing. Paper presented at the Annual Meeting of the American Educational Research Association. Washington, D.C. (ERIC Document Reproduction Service NO. ED 290 701)

Gudmundsdottir, S. & Shulman, L. (1987). Pedagogical content knowledge in social studies. Scandinavian Journal of Educational Research, 31, 59-70.

Hashweh, M. Z. (1987). Effects of subject matter knowledge in the teaching of biology and physics. Teaching and Teacher Education, 3, 109-120.

Hofwolt, C. A. (No date). Instructional strategies in the science classroom. In D. Holdzkom & P. B. Lutz, Research within reach: Science education. Washington, D.C.: National Science Teachers Association.

Holmes Group. (1986). Tomorrow's teachers: A report of the Holmes Group. East Lansing, MI: Author.

Livingston, C. & Borko, H. (1989). Expert-novice differences in teaching: A cognitive analysis and implications for teacher education. Journal of Teacher Education, 40(4), 36-42.

Marks, R. (1990). Pedagogical content knowledge: From a mathematical case to a modified conception. Journal of Teacher Education, 41(3), 3-11.

Newman, D. Griffin, P. & Cole, M. (1989). The construction zone: Working for cognitive change in school. Cambridge: Cambridge University Press.

Renaissance Group. (1989). Teachers for the new world: A statement of principles. Cedar Falls, IA: Author.

Schon, D. A. (1987). Educating the reflective practitioner. San Francisco: Jossey-Bass.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15, 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57, 1-22.

Shulman, L. S. (1988). A union of insufficiencies: Strategies for teacher assessment in a period of educational reform. Educational Leadership, vol, pp.

Tamir, P. (1988). Subject matter and related pedagogical knowledge in teacher education. Teaching and Teacher Education, 4, 99-110.

Tobin, K. & Garnett, P. (1988). Exemplary practice in science classrooms. Science Education, 72, 197-208.

Wilson, S. M., Shulman, L. S., & Richert, A. E. (1987). '150 different ways' of knowing: Representation of knowledge in teaching. In J. Calderhead (Ed.). Exploring teachers' thinking (pp. 104-124). London: Cassell.

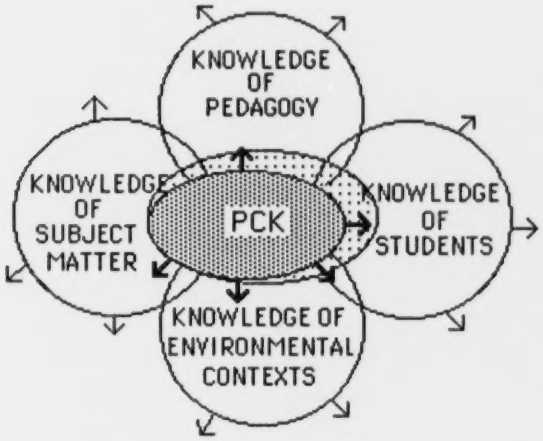

FIGURE 1. PCK model for the beginning teacher.

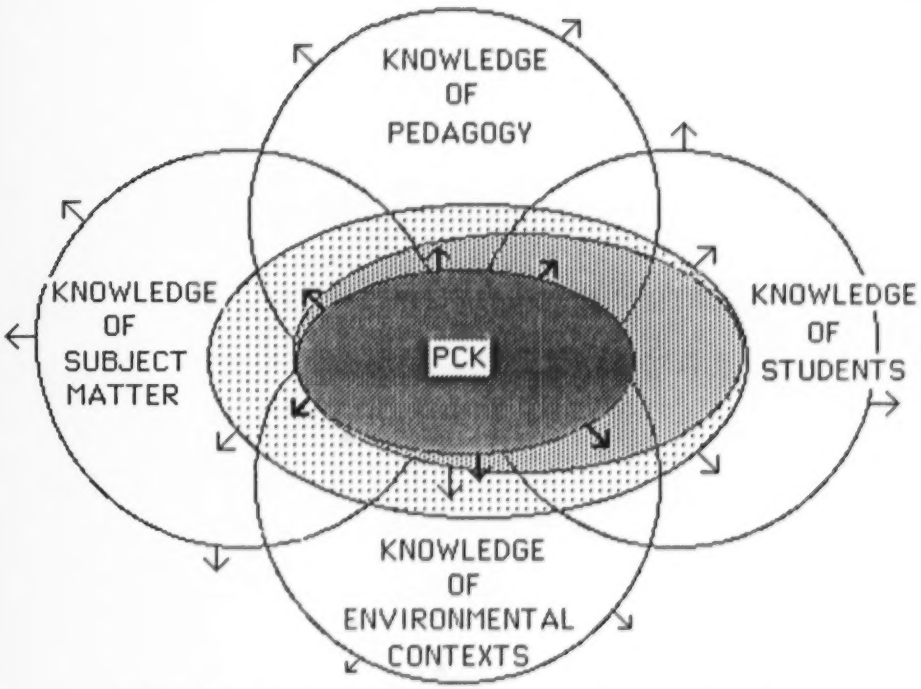

FIGURE 2. PCK model for the experienced teacher.